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COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY C'

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

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Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

March 1984

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U.S. Department of Energy
as part of the
Formerly Utilized Sites -- Remedial Action Program

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COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY C' NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (presently referred to as the Niagara Falls Storage Site (NFSS) and off-site properties), approximately 3 km northeast of Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations; however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and, following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612-hectare site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.¹

Modern Landfill, Inc. is the current owner of a tract from the NFSS, identified as off-site property C' (see Figure 1). A radiological survey of that tract, conducted during October 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property C'. (This tract of 5.2 hectares actually includes about 1.2 hectares of the original property C; however, since the ownership of that section is now the same as that of property C' it has been considered as a single parcel for the purposes of this survey.) This property is unused and is overgrown with heavy brush, weeds, and trees. The eastern portion of the property contains many swampy regions and has been designated by the state of

New York as a "wetlands" area. The property is fenced on the east, north, and west sides. SCA Chemical Services, Inc. owns the property north and east of area C'; Modern Landfill, Inc. owns the property to the south; and the property to the west is part of the Department of Energy's Niagara Falls Storage Site. An unused and partially removed railroad track forms the southern property boundary. Unused tracks also cross the property near the eastern perimeter.

Radiological History

There is no record of contaminated material burial on this property.¹ The 1971-72 survey identified an area of surface contamination along the railroad track near the south-central portion of the property.² Some removal of surface soil was performed as a result of those findings. Elevated direct radiation levels have been measured along the railroad tracks (possibly due to natural materials in the roadbed ballast) and near the western boundary, a result of the radium bearing residues stored in the tower on the adjacent DOE property.^{2,3}

SURVEY PROCEDURES

The comprehensive survey of off-site property C' was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during October, 1983. The survey was in accordance with a plan dated March 18, 1983, approved by the Department of Energy's Office of Nuclear Energy. The objectives and procedures from that plan are presented in this section.

Objective

The objective of the survey was to provide a comprehensive assessment of the radiological conditions and associated potential health effects, if any, on property C'. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil, and
4. concentrations of radionuclides in subsurface water.

Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying and a 20 m system was established. These operations were performed by McIntosh and McIntosh of Lockport, NY, under subcontract. The grid system is shown on Figure 3.
2. Walkover surface scans were conducted at 1-2 m intervals over all accessible areas of the property. Portable gamma NaI(Tl) scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted.
3. Because numerous locations of elevated surface radiation levels were identified in the section of property bounded by grid lines 670N, 720N, 940E, and 1000E, this area was subdivided into 10 m grid blocks to provide additional systematic soil sampling points.
4. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 20 m grid intervals. Measurements were performed using portable gamma scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour ($\mu\text{R/h}$) was in accordance with cross calibration with a pressurized ionization chamber.
5. Beta-gamma dose rate measurements were performed 1 cm above the surface at 20 m grid intervals. These measurements were conducted using thin-window ($<7 \text{ mg/cm}^2$) G-M detectors and

portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of non-penetrating beta and low-energy gamma radiations. Meter readings were converted to dose rates in microrads per hour ($\mu\text{rad/h}$), based on cross calibration with a thin-window ionization chamber.

6. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at 20 m grid intervals and at 10 m grid intervals within the subdivided area described in item 3, above.
7. At locations of elevated surface radiation levels, identified by the walkover scan, exposure rates at contact and 1 m above the surface and beta-gamma dose rates at 1 cm above the surface were measured. Surface samples were obtained from selected locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source.
8. Shallow (about 1.2 m maximum depth) boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface samples. Ten boreholes were drilled by survey team personnel, using a portable motorized auger unit. The locations of these boreholes are shown on Figure 4.

A gamma scan of the boreholes was performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were determined by measuring gamma radiation at 15-30 cm intervals between the surface and hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of each

borehole with an ORAU designed sampling tool. Water samples were also collected from two of the boreholes.

9. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on the NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 5.

Sample Analyses and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for Cs-137, U-235, U-238, Th-232, and other gamma emitters.

Additional information concerning analytical equipment and procedures is contained in Appendix A.

Results of this survey were compared to the applicable guidelines for formerly utilized radioactive materials handling sites, which are presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 5) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μ R/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, systematically measured at 20 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 8 to 23 $\mu\text{R/h}$ (average 11 $\mu\text{R/h}$). At surface contact, the rates ranged from 8 to 21 $\mu\text{R/h}$ (average 11 $\mu\text{R/h}$). Beta-gamma dose rates ranged from 9 to 71 $\mu\text{rad/h}$ (average 21 $\mu\text{rad/h}$). Measurements performed with the detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate at these locations is due to nonpenetrating beta or low-energy photon radiations. Levels were generally higher along the western boundary -- the area nearest the site of the stored radium bearing residues.

The walkover survey identified numerous small isolated areas with elevated surface radiation levels. These locations are indicated on Figure 6 and direct radiation levels at these locations are presented in Table 3. Contact gamma exposure rates ranged from 14 to 320 $\mu\text{R/h}$. The maximum contact exposure rate was at grid coordinate 684N, 1002E. Gamma exposure rates at 1 m above the surface and contact beta-gamma dose rates ranged from 10 to 29 $\mu\text{R/h}$ and 36 to 5890 $\mu\text{rad/h}$ respectively. The highest dose rate was also at grid location 684N, 1002E. Sampling at many of these locations did not significantly reduce the direct radiation levels, suggesting that contamination at these points is diffused rather than in small discrete deposits.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil from 20 m grid intervals. These samples contained Ra-226

concentrations ranging from 0.48 to 7.18 pCi/g. Approximately 26% of the samples had Ra-226 levels above the range measured in baseline soil. Samples collected from those portions of the railroad bed, which have not been removed, consisted primarily of rock ballast with naturally occurring concentrations of Ra-226 and U-238 ranging from about 2 to 7 pCi/g. The sample from coordinate 700N, 1160E contained 8.11 pCi/g of Cs-137, and the sample from 700N, 960E contained 21.8 pCi/g of U-238. Numerous other samples contained concentrations of U-235, U-238, Cs-137, and Th-232 up to approximately twice the ranges in baseline soil.

Concentrations of radionuclides in surface samples from 10 m intervals in the area of the subdivided grid are presented in Table 5. Approximately 60% of these samples contained elevated Ra-226 concentrations; the highest level was 9.95 pCi/g at 680N, 970E. U-238 concentrations were also elevated in many of these samples, with the maximum level of 55.8 pCi/g at 690N, 990E. Cs-137 and Th-232 concentrations were only slightly above those in baseline samples. These results indicate that the radionuclide levels are generally higher along grid lines 670N and 680N, near the railroad track.

All surface samples, collected from areas of elevated direct radiation identified by the surface scan, contain elevated levels of Ra-226 and U-238 (see Table 6). The maximum Ra-226 concentration was 22,500 pCi/g in sample B27 from 706N, 948E; however, sample B14 from 680N, 960E contained several small white chips with a total content of 0.60 μ Ci of Ra-226. Samples B18 and B19 contained U-238 concentrations of 10,800 and 14,800 pCi/g; respectively; U-235 concentrations in these two samples indicated naturally occurring uranium isotopic abundances. Many of the higher radium and uranium concentrations are associated with surface debris or are in the form of small white or yellow chips and flakes.

Cs-137 and Th-232 concentrations in these samples are generally in the range of baseline levels or are below the detection sensitivity limits of the analytical procedures.

Borehole Gamma Logging Measurements

The results of gamma scintillation measurements performed in boreholes indicated that contamination is limited to the upper 15 to 30 cm of soil. Gamma logging data was not used to quantify radionuclide concentrations in the subsurface soil because of the varying ratios of Ra-226, U-235, U-238, Cs-137, and Th-232 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Table 7 presents the radionuclide concentrations measured in soil samples from boreholes. Boreholes H1-H3, located to provide a representative coverage of the property, did not contain levels of radionuclides differing significantly from baseline levels. Boreholes H4-H11 were at locations of "hot spots," identified by the walkover scan. Concentrations of Ra-226 and/or U-238 are elevated in most of the subsurface samples; the maximum subsurface Ra-226 level is 7.68 pCi/g from the 0.6 m depth in borehole H5, and the maximum U-238 level is 36.0 pCi/g at the 1.0 m depth in borehole H8. There are no significant levels of Cs-137 or Th-232 in the subsurface samples.

Radionuclide Concentrations in Subsurface Water Samples

Concentrations of radionuclides, measured in water samples from two boreholes, are presented in Table 8. Both samples contained elevated gross alpha concentrations; the higher level was 278 pCi/l in the sample from borehole H9 (surface soil at that borehole location contained 1900 pCi/g of Ra-226). Ra-226 concentrations in these samples were W1, 0.98 pCi/l and W2, 0.92 pCi/l.

COMPARISON OF RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of the off-site properties at NFSS are presented in Appendix B. Exposure rates at 1 m above the ground surface of 29 μ R/h maximum and 11 μ R/h average are well below 60 μ R/h,

which is the continuous exposure rate equivalent to approximately 500 mrem/yr - the recommended limit for the general public. Surface soil samples from 20 m grid intervals either contain less than 5 pCi/g of Ra-226 above baseline levels or their Ra-226 concentrations are naturally occurring (railroad ballast). The south-central portion of the property contains general areas and isolated "hot spots" with surface Ra-226 and U-238 concentrations exceeding the guidelines of 5 pCi/g and 150 pCi/g, respectively, above baseline levels. These areas and "hot spots" are indicated on Figure 7 and listed in Table 9. The isolated contaminated spots can be eliminated by removal of a small volume (1 m^3 each) of surface soil. Removal of the areas of general surface contamination can be accomplished by removal of approximately 21 m^3 of soil. No subsurface contamination exceeding guideline levels was identified on this property.

Both water samples contained concentrations exceeding the EPA Interim Drinking Water Standards of 15 pCi/l gross alpha and 50 pCi/l gross beta. The Ra-226 concentrations in these samples were below the EPA standard of 5 pCi/l total radium.

SUMMARY

A comprehensive survey of off-site property C' at the Niagara Falls Storage Site was conducted during October, 1983. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples.

The results of the survey indicate elevated direct radiation levels on the western portion of the property, due to residues stored on the adjacent DOE site. Ra-226 and U-238 contamination in surface (0-15 cm) soil in the south-central portion of the property, believed to be the result of previous MED/AEC activities, exceeds the guidelines for formerly utilized sites. This contamination also produces elevated direct radiation levels on that area of the property. Water sampling indicates that small amounts of radioactive material may also be entering the shallow ground water table

in the immediate vicinity of some surface contamination. Contaminated areas could be eliminated by removal of an estimated 30-40 m³ of soil (refer to Table 9 and Figure 7).

Although there are areas of elevated direct radiation and small isolated locations of contaminated residues on portions of this property, the radiation and radionuclide levels do not pose potential health risks. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties.

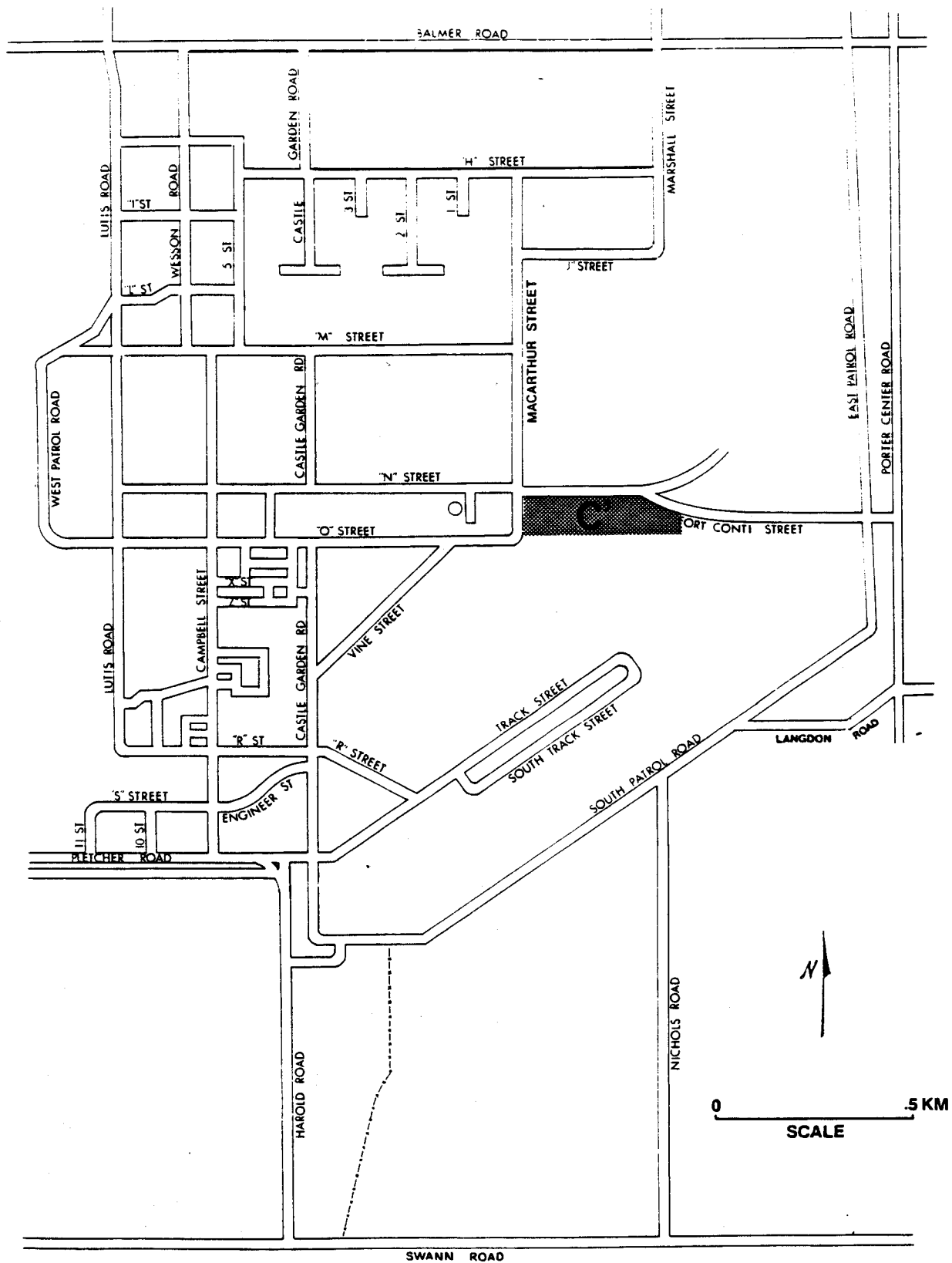


FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property C'.

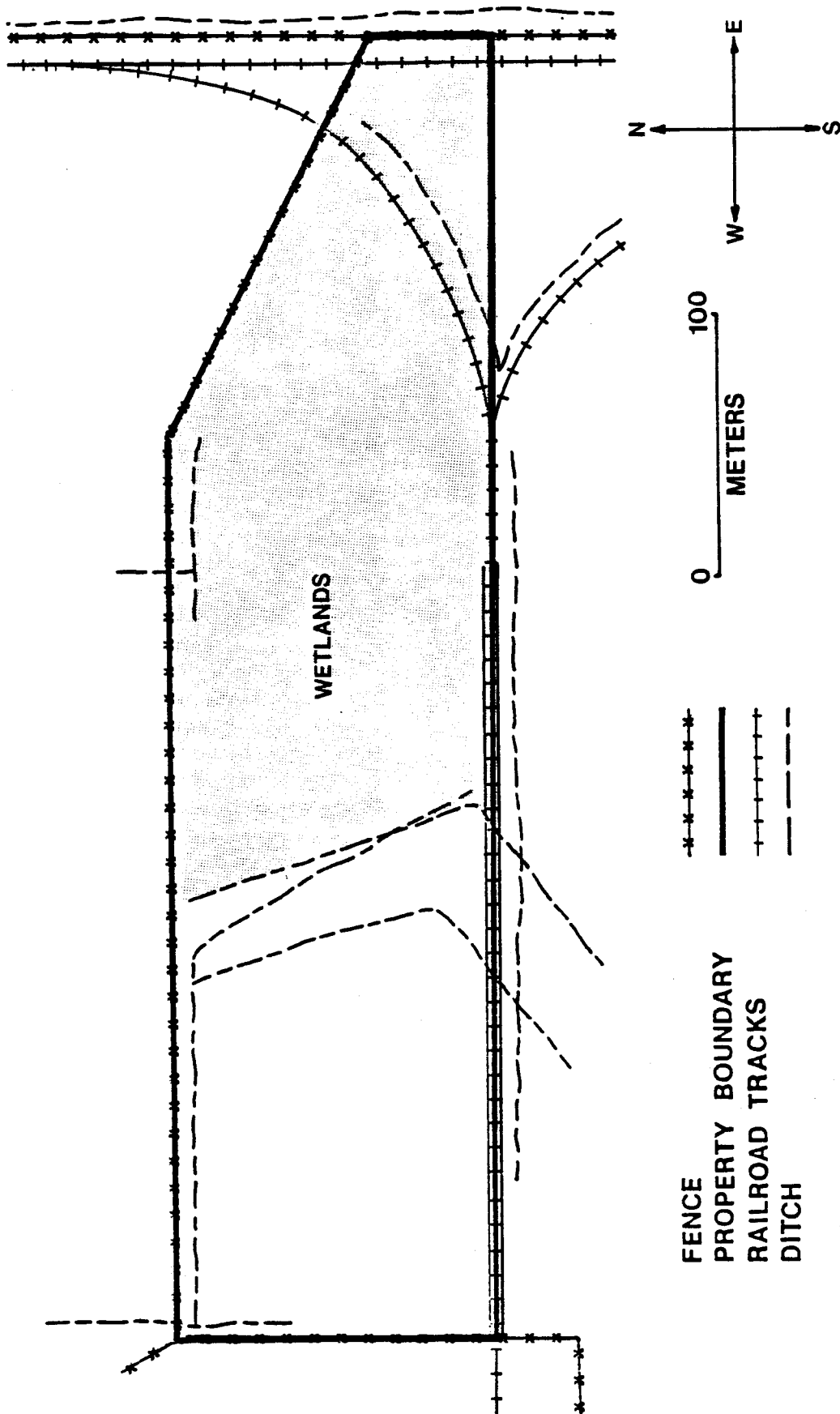


FIGURE 2. Plan View of NFSS Off-Site Property C' Indicating Prominent Surface Features.

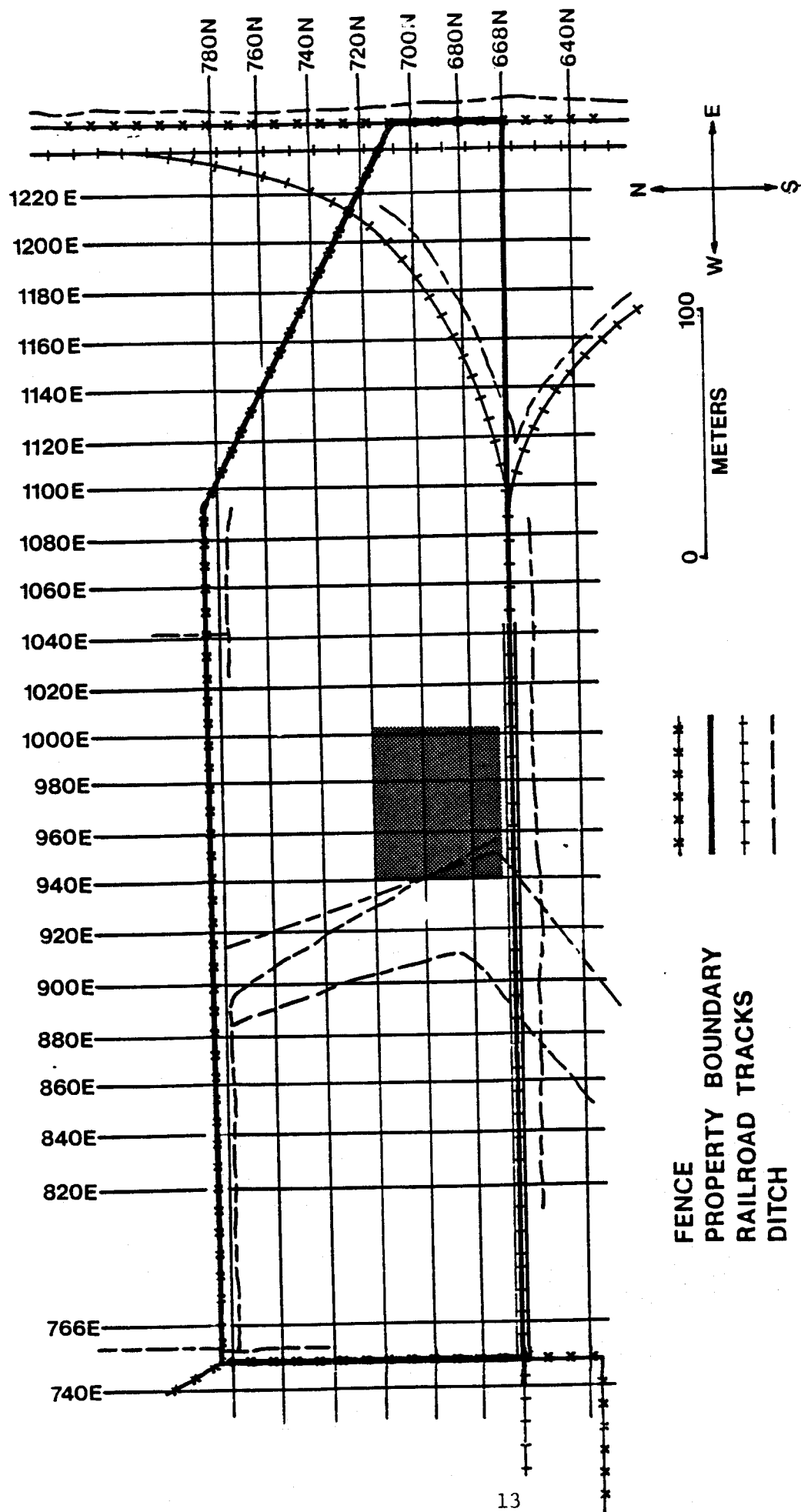


FIGURE 3. Plan View of NFSS Off-Site Property C' Indicating the Grid System Established for Survey Reference. (Shaded area is region subdivided into 10 m grids for additional sampling.)

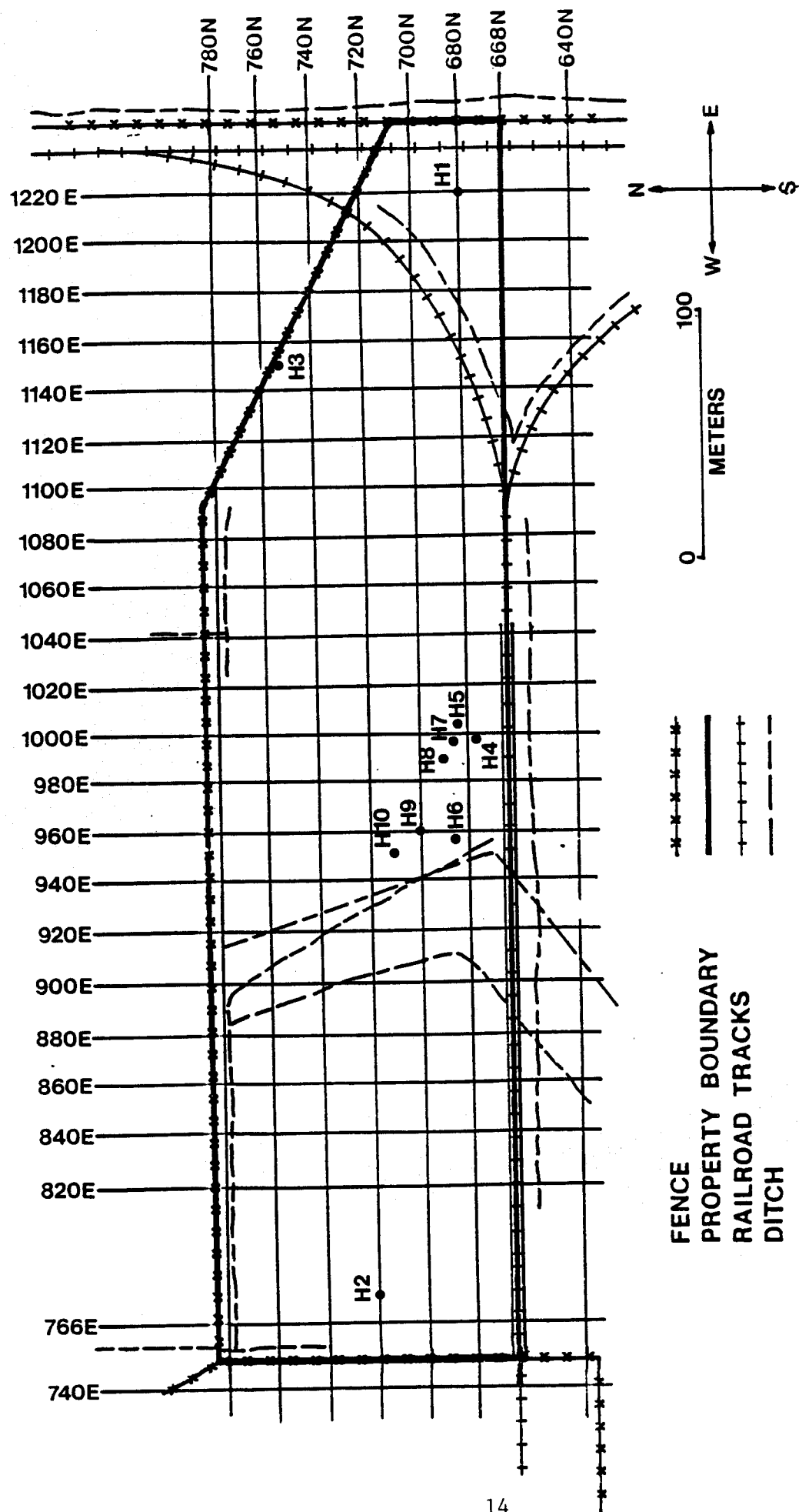


FIGURE 4. Locations of Boreholes for Subsurface Investigations.

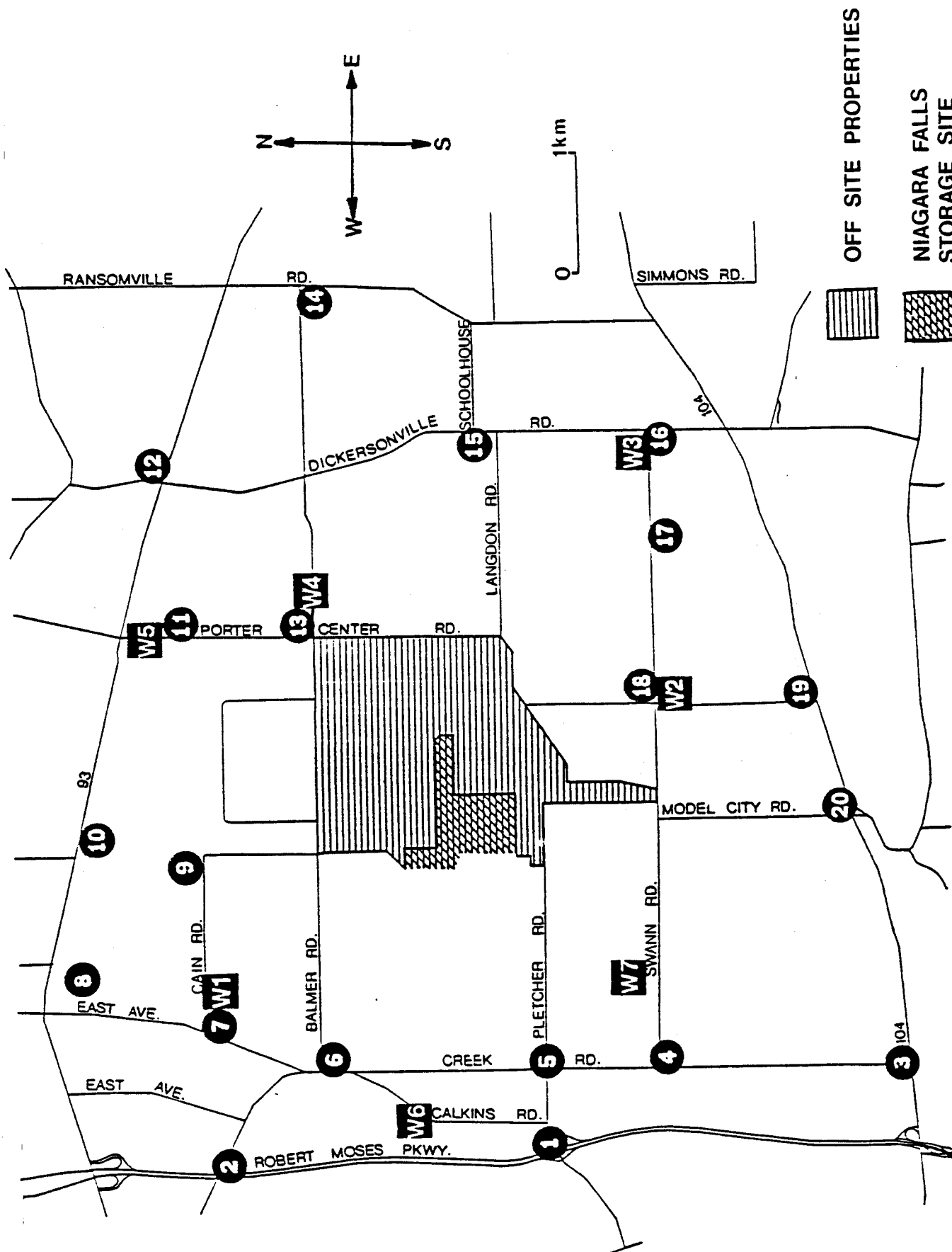


FIGURE 5. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

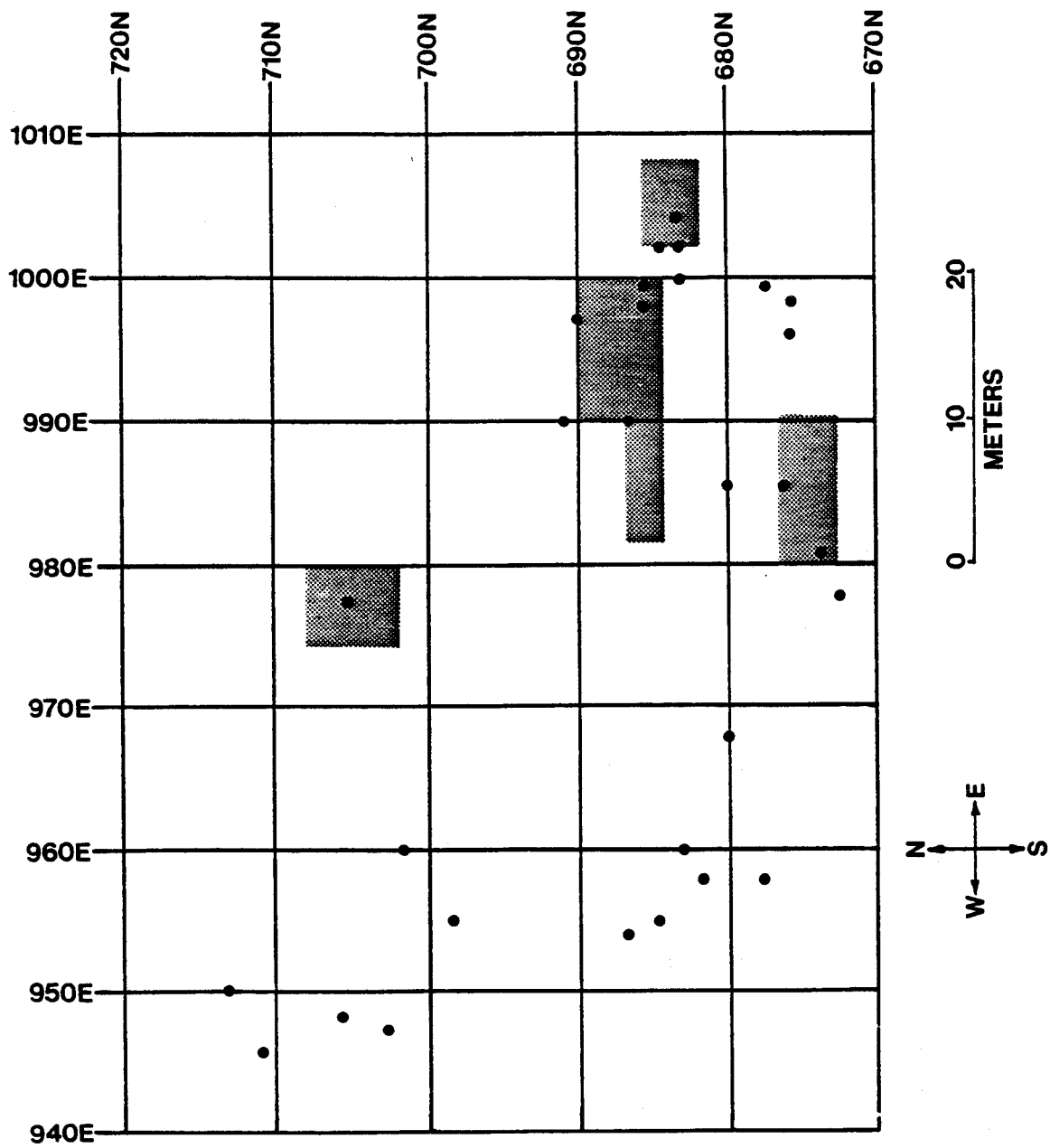


FIGURE 6. Locations of Surface Areas of Elevated Direct Radiation.

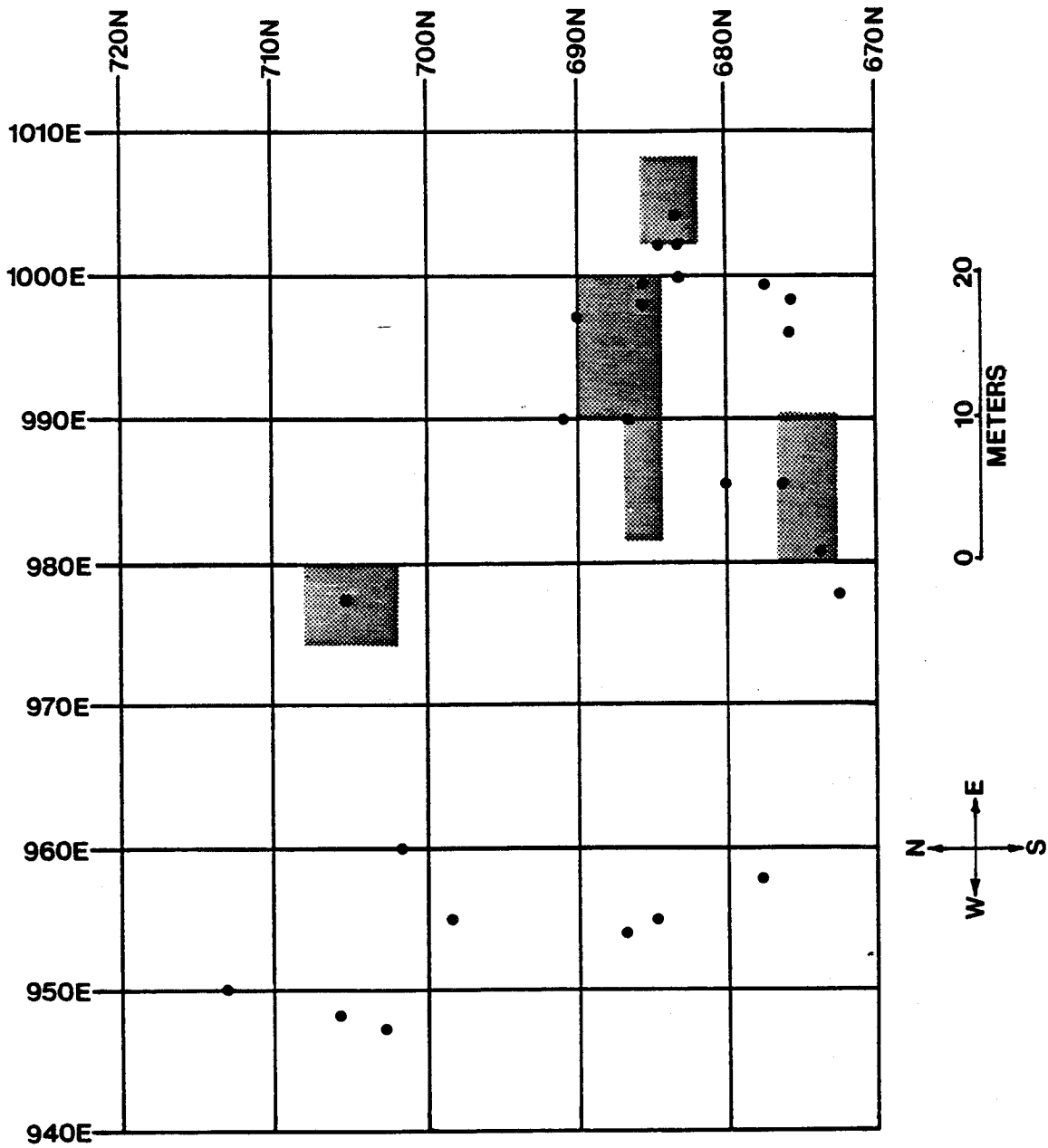


FIGURE 7. Map of NFSS Off-Site Property C' Indicating Areas Where Radionuclide Concentrations in Soil Exceed Criteria.

TABLE 1-A
BACKGROUND EXPOSURE RATES
AND
BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL

Location ^a	Exposure Rate ^b (μ R/h)	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 \pm 0.16 ^c	<0.19	<2.89	0.70 \pm 0.46	0.29 \pm 0.08
2	6.8	0.75 \pm 0.19	<0.19	<3.35	<0.22	0.24 \pm 0.08
3	8.3	0.71 \pm 0.18	0.46 \pm 0.41	<3.72	0.88 \pm 0.33	0.34 \pm 0.09
4	7.9	0.67 \pm 0.18	<0.22	<4.10	1.18 \pm 0.35	0.12 \pm 0.07
5	7.3	0.70 \pm 0.16	<0.17	<3.34	0.68 \pm 0.24	0.14 \pm 0.07
6	7.7	0.50 \pm 0.15	<0.16	<2.33	0.52 \pm 0.38	0.17 \pm 0.09
7	7.7	0.63 \pm 0.13	<0.17	<2.73	0.83 \pm 0.24	0.35 \pm 0.08
8	7.6	0.59 \pm 0.12	<0.14	<2.20	0.54 \pm 0.23	<0.02
9	7.1	0.63 \pm 0.20	<0.23	<4.16	0.83 \pm 0.38	0.69 \pm 0.11
10	7.1	0.70 \pm 0.16	<0.19	<2.98	<0.18	0.69 \pm 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 \pm 0.31	0.48 \pm 0.14
12	7.1	0.48 \pm 0.13	<0.16	<2.84	0.65 \pm 0.26	0.68 \pm 0.10
13	6.7	0.57 \pm 0.14	<0.17	<2.36	0.49 \pm 0.26	0.41 \pm 0.08
14	6.8	0.68 \pm 0.17	<0.19	<3.24	0.67 \pm 0.25	0.70 \pm 0.10
15	8.2	0.65 \pm 0.14	<0.17	<3.20	0.72 \pm 0.35	0.23 \pm 0.08
16	7.4	0.91 \pm 0.17	<0.71	<3.58	0.83 \pm 0.28	0.61 \pm 0.09
17	7.0	0.48 \pm 0.14	<0.16	<2.73	0.32 \pm 0.22	0.38 \pm 0.08
18	7.7	0.73 \pm 0.16	<0.18	6.26 \pm 9.23	<0.23	0.32 \pm 0.12
19	8.8	1.22 \pm 0.22	<0.23	<3.79	1.08 \pm 0.49	1.05 \pm 0.13
20	8.6	0.83 \pm 0.17	<0.21	<3.59	0.84 \pm 0.29	0.08 \pm 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	<0.18 to 1.18	<0.02 to 1.05

^a Refer to Figure 5.

^b Measured at 1 m above the surface.

^c Errors is 2 σ based on counting statistics only.

TABLE 1-B
RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location ^a	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 \pm 0.93 ^b	4.79 \pm 1.15
W2	0.95 \pm 0.94	9.17 \pm 1.31
W3	0.55 \pm 0.78	2.73 \pm 1.05
W4	0.63 \pm 0.89	5.37 \pm 1.17
W5	0.73 \pm 0.68	<0.64
W6	1.87 \pm 1.84	14.3 \pm 2.4
W7	1.16 \pm 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

^a Refer to Figure 5.

^b Errors are 2 σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS
MEASURED AT 20 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface (μ R/h)	Gamma Exposure Rates at the Surface (μ R/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μ rad/h)
N	E			
668	766	17	18	71
668	820	13	13	62
668	840	12	12	53
668	860	12	12	18
668	880	12	13	34
668	900	12	14	24
668	920	12	13	35
668	940	12	12	31
668	960	12	13	59
668	980	12	12	54
668	1000	13	13	17
668	1020	13	14	41
668	1040	12	12	21
668	1060	12	12	32
668	1080	12	13	26
668	1100	12	12	61
668	1120	12	13	36
668	1140	11	11	25
668	1160	9	9	18
668	1180	10	10	17
668	1200	8	9	19
668	1220	9	9	12
668	1240	12	14	51
680	766	17	18	71
680	820	13	12	34
680	840	13	12	12
680	860	12	10	41
680	880	10	10	37
680	900	10	10	29
680	920	9	9	25
680	940	9	9	16
680	960	12	10	13
680	980	13	12	52
680	1000	17	14	28
680	1020	12	12	18
680	1040	10	10	10
680	1060	9	10	17
680	1080	10	10	24
680	1100	12	10	17
680	1120	10	10	16
680	1140	12	12	22

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 20 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface ($\mu\text{R/h}$)	Gamma Exposure Rates at the Surface ($\mu\text{R/h}$)	Beta-Gamma Dose Rates at 1 cm Above the Surface ($\mu\text{rad/h}$)
N	E			
680	1160	12	13	30
680	1180	9	9	16
680	1200	9	8	12
680	1220	9	9	12
680	1240	12	14	41
700	766	20	18	35
700	820	14	14	27
700	840	12	12	25
700	860	10	10	26
700	880	10	10	17
700	900	10	10	20
700	920	10	10	24
700	940	10	9	19
700	960	12	13	64
700	980	10	10	19
700	1000	12	12	15
700	1020	10	10	29
700	1040	10	9	36
700	1060	9	10	10
700	1080	10	10	16
700	1100	9	9	26
700	1120	9	9	12
700	1140	9	10	10
700	1160	9	10	14
700	1180	12	13	27
700	1200	9	9	25
700	1220	9	9	15
700	1240	12	14	54
720	766	18	17	46
720	820	14	14	36
720	840	13	12	52
720	860	12	12	31
720	880	10	10	32
720	900	9	9	22
720	920	10	10	20
720	940	9	9	26
720	960	8	8	15
720	980	8	9	19
720	1000	12	12	22
720	1020	12	12	22
720	1040	10	10	20

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 20 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface (μ R/h)	Gamma Exposure Rates at the Surface (μ R/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μ rad/h)
N	E			
720	1060	9	10	20
720	1080	9	9	22
720	1100	9	10	10
720	1120	9	9	15
720	1140	10	9	9
720	1160	9	10	14
720	1180	9	9	45
720	1200	12	12	37
720	1220	9	10	11
740	766	20	20	48
740	820	14	14	37
740	840	13	13	30
740	860	12	12	32
740	880	10	10	23
740	900	10	10	16
740	920	9	9	23
740	940	10	10	11
740	960	8	10	19
740	980	8	9	19
740	1000	12	12	29
740	1020	9	9	19
740	1040	10	9	13
740	1060	9	9	25
740	1080	9	9	9
740	1100	9	9	19
740	1120	9	9	19
740	1140	9	9	19
740	1160	9	9	25
740	1180	8	9	16
760	766	21	20	53
760	820	14	14	33
760	840	12	12	32
760	860	12	12	13
760	880	10	10	29
760	900	10	10	39
760	920	10	10	29
760	940	9	9	12
760	980	8	9	26
760	1000	12	12	13
760	1020	10	10	27
760	1040	9	10	a

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 20 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface (μ R/h)	Gamma Exposure Rates at the Surface (μ R/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μ rad/h)
N	E			
760	1060	9	9	23
760	1080	9	9	19
760	1100	9	9	9
760	1120	9	9	22
760	1140	9	10	16
780	766	20	18	57
780	820	14	14	27
780	840	12	13	22
780	860	12	12	23
780	880	10	10	40
780	900	9	9	28
780	920	10	10	21
780	940	10	9	9
780	960	8	9	12
780	980	8	8	31
780	1000	11	11	21
780	1020	11	12	13
780	1040	9	9	a
780	1060	9	9	15
780	1080	9	9	29
780	1100	10	9	26
786	753	23	20	63
786	766	20	21	45
786	820	14	13	32
786	840	13	14	30
786	860	12	12	25
786	880	10	10	32
786	900	9	9	22
786	920	9	9	9
786	940	9	9	16
786	960	8	9	13
786	980	8	8	11
786	1000	10	9	15
786	1020	10	12	29
786	1040	9	9	a
786	1060	10	12	13
786	1080	10	10	20

^a Grid point inaccessible due to surface water, heavy brush, or hornets nests.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location ^a		Exposure Rate ($\mu\text{R/h}$)		Surface Dose Rate		Sample		Contact Exposure Rate	
N	E	Contact	1 m Above Surface	($\mu\text{rad/h}$)	Identification ^b	After Sample Removal	($\mu\text{R/h}$)		
673	977	22	14	95	B1		20		
673-676	980-990	14-36	---	---	---		---		
674	981	24	12	70	B2		27		
676	985	36	14	36	B3		44		
676	996	130	29	660	B4		83		
676	998	48	20	180	B5		62		
677	957	50	14	74	B6		58		
677	999	33	26	100	B7		40		
680	968	83	12	980	B8		13		
680	986	35	18	94	B9		20		
683	957	210	12	1440	B10		12		
683	1000	24	22	64	B11		22		
682-686	1002-1006	29-110	---	---	---		---		
683	1002	58	26	360	B12		67		
683	1004	110	22	370	B13		110		
684	960	47	16	110	B14		17		
684-686	982-990	27-32	---	---	---		---		
684	1002	320	26	5890	B15		110		
685	955	250	18	700	B16		83		
685-690	990-1000	20-110	---	---	---		---		
685	997	110	26	750	B17		87		
685	999	67	24	400	B18		95		
686	990	110	18	2580	B19		120		
687	954	75	13	260	B20		20		
690	997	62	20	340	B21		67		
691	990	44	13	490	B22		50		
698	955	83	20	190	B23		160		
702	960	57	17	170	B24		20		
703	947	23	10	69	B25		17		
703-708	975-980	14-39	---	---	---		---		
705	977	39	20	110	B26		110		
706	948	54	16	160	B27		22		
711	946	110	10	940	B28		12		
713	950	30	12	110	B29		35		

^a Refer to Figure 6.

^b Soil concentrations presented in Table 6.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
668		0.97 ± 0.31 ^a	<0.30	4.92 ± 1.95	<0.04	2.00 ± 0.55
668	820	1.01 ± 0.30	<0.22	1.21 ± 1.45	<0.04	0.72 ± 0.58
668	840	1.01 ± 0.28	<0.25	1.88 ± 2.28	<0.05	1.31 ± 0.40
668	860	0.84 ± 0.20	<0.14	1.04 ± 0.51	0.03 ± 0.04	0.62 ± 0.28
668	880	2.06 ± 0.33	<0.24	1.73 ± 0.86	0.11 ± 0.10	0.46 ± 0.27
668	900	0.86 ± 0.24	<0.20	0.76 ± 1.85	<0.03	0.67 ± 0.40
668	920	1.21 ± 0.25	<0.32	0.44 ± 1.73	<0.04	1.69 ± 0.44
668	940	0.94 ± 0.24	<0.29	<0.97	<0.05	1.41 ± 0.36
668	960	6.35 ± 0.49	<0.25	4.06 ± 0.91	<0.03	1.14 ± 0.43
668	980	4.89 ± 0.85	1.05 ± 1.20	1.71 ± 5.10	0.34 ± 0.15	1.65 ± 1.08
668	1000	7.18 ± 0.99	<0.61	7.40 ± 2.07	<0.11	<0.57
668	1020	5.91 ± 0.90	<0.61	3.12 ± 1.79	0.99 ± 0.32	1.49 ± 0.99
668	1040	3.64 ± 0.71	<0.54	1.80 ± 2.69	0.85 ± 0.35	1.22 ± 0.82
668	1060	5.30 ± 1.04	<0.53	6.09 ± 2.15	0.42 ± 0.17	1.34 ± 0.87
668	1080	5.51 ± 0.94	2.41 ± 1.25	2.96 ± 4.86	0.36 ± 0.31	0.83 ± 1.26
668	1100	3.81 ± 0.78	0.55 ± 1.44	2.74 ± 4.26	0.33 ± 0.30	1.90 ± 0.84
668	1120	6.65 ± 1.26	0.61 ± 1.77	1.97 ± 3.51	0.35 ± 0.18	1.16 ± 1.17
668	1140	0.80 ± 0.28	<0.17	2.17 ± 1.37	0.99 ± 0.16	0.50 ± 0.30
668	1160	0.68 ± 0.28	<0.39	5.49 ± 2.71	0.52 ± 0.14	0.66 ± 0.40
668	1180	1.16 ± 0.31	<0.21	3.63 ± 0.88	0.66 ± 0.19	0.97 ± 0.36
668	1200	1.41 ± 0.34	<0.36	4.51 ± 4.54	1.44 ± 0.24	1.20 ± 0.59
668	1220	0.86 ± 0.35	<0.27	2.58 ± 1.96	1.19 ± 0.21	1.18 ± 0.49
668	1242	0.85 ± 0.33	<0.27	1.50 ± 2.84	0.90 ± 0.16	0.94 ± 0.45
680	766	0.88 ± 0.24	0.40 ± 0.50	1.30 ± 1.39	0.10 ± 0.13	0.58 ± 0.39
680	820	1.04 ± 0.31	<0.37	0.74 ± 1.10	0.61 ± 0.15	1.22 ± 0.68
680	840	0.95 ± 0.24	<0.16	1.42 ± 0.74	0.12 ± 0.09	1.10 ± 0.44
680	860	0.76 ± 0.30	<0.21	1.26 ± 1.36	0.58 ± 0.13	0.49 ± 0.27
680	880	1.04 ± 0.29	<0.26	2.16 ± 1.86	0.69 ± 0.17	1.23 ± 0.66
680	900	0.96 ± 0.28	<0.21	2.29 ± 0.81	0.71 ± 0.16	1.27 ± 0.43
680	920	1.24 ± 0.34	<0.40	6.32 ± 3.95	0.71 ± 0.15	1.08 ± 0.61
680	940	1.55 ± 0.46	<0.42	6.81 ± 2.27	0.83 ± 0.18	1.35 ± 0.68
680	960	2.10 ± 0.35	0.95 ± 0.55	9.08 ± 1.22	<0.07	0.98 ± 0.44
680	980	3.29 ± 0.53	0.88 ± 1.06	20.8 ± 4.8	<0.08	0.87 ± 0.55
680	1000	4.46 ± 0.54	0.82 ± 1.04	8.23 ± 5.11	0.12 ± 0.18	1.25 ± 0.65
680	1020	1.09 ± 0.26	<0.20	2.34 ± 0.79	0.94 ± 0.18	1.20 ± 0.47
680	1040	1.06 ± 0.48	<0.30	2.48 ± 2.52	0.84 ± 0.16	0.48 ± 0.39
680	1060	1.15 ± 0.49	<0.42	7.66 ± 2.70	2.12 ± 0.24	2.01 ± 0.62
680	1080	1.01 ± 0.40	<0.42	2.05 ± 4.09	1.36 ± 0.20	1.05 ± 0.54
680	1100	0.83 ± 0.26	<0.18	2.14 ± 0.69	0.10 ± 0.10	0.64 ± 0.30
680	1120	1.31 ± 0.41	<0.37	5.09 ± 1.57	0.75 ± 0.15	1.18 ± 0.35
680	1140	1.34 ± 0.41	0.44 ± 0.72	<0.89	0.99 ± 0.19	0.88 ± 0.46

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL
FROM 20 M GRID INTERVALS

Grid Location N E	Radionuclide Concentrations (pCi/g)			
	Ra-226	U-235	U-238	Th-232
680 1160	4.35 ± 0.76	<0.61	6.35 ± 2.59	0.29 ± 0.22
680 1180	1.16 ± 0.36	<0.26	4.49 ± 2.67	0.81 ± 0.15
680 1200	0.75 ± 0.23	<0.21	3.29 ± 1.11	0.87 ± 0.18
680 1220	0.95 ± 0.33	<0.33	7.21 ± 5.64	0.84 ± 0.25
680 1240	1.31 ± 0.40	<0.28	1.75 ± 1.78	1.34 ± 0.20
700 776	1.06 ± 0.25	<0.28	0.82 ± 2.00	<0.05
700 820	0.91 ± 0.34	<0.35	2.27 ± 1.92	0.60 ± 0.14
700 840	0.78 ± 0.26	<0.16	1.64 ± 0.65	0.62 ± 0.15
700 860	0.98 ± 0.28	0.29 ± 0.53	1.33 ± 1.33	0.69 ± 0.16
700 880	0.65 ± 0.29	<0.19	2.20 ± 1.53	0.49 ± 0.13
700 900	0.80 ± 0.25	<0.29	1.52 ± 2.22	0.94 ± 0.16
700 920	1.74 ± 0.43	0.41 ± 1.04	2.48 ± 4.07	0.45 ± 0.15
700 940	1.05 ± 0.35	<0.22	1.59 ± 1.07	0.71 ± 0.16
700 960	4.83 ± 0.68	2.06 ± 1.09	21.8 ± 2.6	0.28 ± 0.16
700 980	1.19 ± 0.41	0.66 ± 0.73	6.55 ± 3.90	0.51 ± 0.15
700 1000	1.14 ± 0.35	<0.26	4.29 ± 2.39	0.76 ± 0.19
700 1020	0.94 ± 0.54	0.58 ± 0.69	2.51 ± 3.07	0.80 ± 0.19
700 1040	0.99 ± 0.40	<0.42	5.55 ± 2.05	0.69 ± 0.20
700 1060	0.99 ± 0.29	<0.20	1.82 ± 1.08	0.65 ± 0.15
700 1080	0.96 ± 0.43	<0.33	2.20 ± 2.52	0.38 ± 0.14
700 1100	0.81 ± 0.26	<0.39	3.94 ± 2.11	2.96 ± 0.33
700 1120	0.61 ± 0.20	<0.19	<0.69	0.51 ± 0.12
700 1140	1.01 ± 0.31	<0.24	2.13 ± 1.82	0.78 ± 0.14
700 1160	1.43 ± 0.84	<0.70	6.67 ± 5.55	8.11 ± 0.92
700 1180	4.41 ± 0.90	0.65 ± 1.05	4.24 ± 1.86	0.27 ± 0.15
700 1200	0.61 ± 0.20	<0.34	3.44 ± 1.30	0.66 ± 0.15
700 1220	1.36 ± 0.36	<0.25	3.90 ± 1.09	1.21 ± 0.19
700 1242	0.80 ± 0.38	<0.30	2.02 ± 2.28	0.94 ± 0.21
720 766	0.60 ± 0.25	0.34 ± 0.40	1.20 ± 1.63	0.23 ± 0.11
720 820	0.76 ± 0.22	0.52 ± 0.66	3.32 ± 1.31	0.69 ± 0.14
720 840	0.90 ± 0.20	<0.14	0.67 ± 1.43	0.63 ± 0.12
720 860	0.63 ± 0.22	<0.25	1.21 ± 2.53	0.57 ± 0.16
720 880	0.66 ± 0.30	<0.21	<0.81	0.51 ± 0.13
720 900	1.58 ± 0.43	<0.25	2.62 ± 2.20	0.76 ± 0.18
720 920	0.99 ± 0.26	<0.33	4.13 ± 1.40	0.91 ± 0.15
720 940	0.66 ± 0.39	<0.21	1.90 ± 0.83	0.43 ± 0.15
720 960	0.88 ± 0.40	0.28 ± 0.62	2.27 ± 2.07	0.65 ± 0.16
720 980	1.16 ± 0.31	<0.37	2.59 ± 2.26	0.78 ± 0.20
720 1000	1.05 ± 0.30	0.25 ± 0.51	4.09 ± 0.95	0.88 ± 0.15
720 1020	0.90 ± 0.30	<0.38	3.25 ± 2.91	1.70 ± 0.28
720 1040	1.08 ± 0.29	<0.43	4.50 ± 1.63	1.16 ± 0.18
720 1060				1.02 ± 0.45
720 1080				1.09 ± 0.59
720 1100				0.38 ± 0.44
720 1120				1.25 ± 0.67
720 1140				1.29 ± 0.48
720 1160				1.57 ± 0.49
720 1180				1.31 ± 0.55
720 1200				1.07 ± 0.53
720 1220				0.96 ± 0.49
720 1240				0.65 ± 0.28
720 1260				1.81 ± 0.54
720 1280				1.30 ± 0.49
720 1300				1.27 ± 0.62
720 1320				0.99 ± 0.69
720 1340				1.03 ± 0.49
720 1360				1.08 ± 0.41
720 1380				1.42 ± 0.47
720 1400				0.45 ± 0.31
720 1420				1.09 ± 0.37
720 1440				1.04 ± 0.50
720 1460				1.03 ± 0.49
720 1480				<0.30
720 1500				0.70 ± 0.31
720 1520				1.40 ± 0.41
720 1540				<0.47
720 1560				1.04 ± 0.58
720 1580				1.05 ± 0.46
720 1600				0.76 ± 0.43
720 1620				0.95 ± 0.70
720 1640				0.46 ± 0.24
720 1660				1.07 ± 0.45
720 1680				0.73 ± 0.36
720 1700				0.75 ± 0.52
720 1720				0.66 ± 0.43
720 1740				0.94 ± 0.45
720 1760				1.17 ± 0.41
720 1780				<0.27
720 1800				1.00 ± 0.49
720 1820				1.57 ± 0.46
720 1840				1.11 ± 0.52
720 1860				1.37 ± 0.56
720 1880				1.02 ± 0.45

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
720	1060	0.70 ± 0.35	0.35 ± 0.67	1.97 ± 1.67	0.89 ± 0.19	0.67 ± 0.28
720	1080	0.88 ± 0.30	<0.30	2.92 ± 2.31	1.40 ± 0.25	0.89 ± 0.49
720	1100	0.85 ± 0.23	<0.19	1.60 ± 0.69	1.05 ± 0.16	0.87 ± 0.31
720	1120	0.90 ± 0.40	<0.25	1.40 ± 2.35	0.56 ± 0.17	1.15 ± 0.39
720	1140	0.79 ± 0.30	<0.25	<0.99	0.88 ± 0.17	0.86 ± 0.35
720	1160	0.64 ± 0.32	<0.42	2.39 ± 2.31	2.66 ± 0.33	1.49 ± 0.69
720	1180	1.50 ± 0.49	<0.29	1.83 ± 3.39	1.37 ± 0.24	1.70 ± 0.67
720	1200	3.98 ± 0.85	<0.51	3.47 ± 2.71	0.37 ± 0.19	0.78 ± 0.83
720	1220	1.08 ± 0.34	<0.28	3.23 ± 2.64	0.71 ± 0.18	0.85 ± 0.51
720	1240	1.04 ± 0.25	<0.25	<0.86	0.17 ± 0.11	0.71 ± 0.36
740	766	0.66 ± 0.20	<0.15	1.59 ± 0.53	0.47 ± 0.10	0.55 ± 0.47
740	820	0.49 ± 0.15	<0.17	0.93 ± 0.95	0.47 ± 0.14	0.48 ± 0.38
740	840	0.96 ± 0.31	<0.23	0.95 ± 2.39	0.83 ± 0.18	1.00 ± 0.65
740	860	0.81 ± 0.25	0.44 ± 0.57	<0.68	0.38 ± 0.16	<0.26
740	880	0.79 ± 0.30	<0.21	1.35 ± 1.21	0.57 ± 0.13	0.62 ± 0.30
740	900	0.70 ± 0.20	<0.16	0.87 ± 0.59	0.48 ± 0.13	0.85 ± 0.40
740	920	0.84 ± 0.26	<0.21	4.30 ± 1.62	0.70 ± 0.17	0.90 ± 0.34
740	940	0.83 ± 0.21	<0.17	1.45 ± 1.25	0.68 ± 0.15	0.76 ± 0.62
740	960	0.94 ± 0.35	<0.29	<0.86	0.77 ± 0.15	1.06 ± 0.48
740	980	0.98 ± 0.28	<0.34	0.53 ± 2.10	0.27 ± 0.13	1.12 ± 0.37
740	1000	0.63 ± 0.24	<0.16	2.34 ± 0.69	0.49 ± 0.16	0.71 ± 0.30
740	1020	1.28 ± 0.35	<0.35	2.53 ± 3.44	1.34 ± 0.24	1.34 ± 0.66
740	1040	1.66 ± 0.49	<0.47	5.18 ± 3.05	0.97 ± 0.27	1.45 ± 0.71
740	1060	0.90 ± 0.32	<0.27	1.90 ± 1.93	1.33 ± 0.23	0.74 ± 0.35
740	1080	0.74 ± 0.25	<0.16	2.03 ± 1.36	0.55 ± 0.15	0.62 ± 0.51
740	1100	0.75 ± 0.30	0.41 ± 0.65	1.98 ± 0.98	0.65 ± 0.18	0.78 ± 0.31
740	1120	0.78 ± 0.32	<0.28	3.01 ± 0.24	0.61 ± 0.14	0.81 ± 0.51
740	1140	1.15 ± 0.30	<0.38	4.27 ± 4.03	0.85 ± 0.15	1.16 ± 0.40
740	1160	0.59 ± 0.30	<0.19	2.45 ± 1.36	0.99 ± 0.18	1.04 ± 0.37
740	1180	1.06 ± 0.25	<0.21	3.47 ± 0.86	2.03 ± 0.23	0.46 ± 0.55
740	1200	1.00 ± 0.36	0.43 ± 0.63	6.79 ± 1.51	0.68 ± 0.14	0.87 ± 0.59
760	766	0.78 ± 0.26	<0.14	1.26 ± 0.58	0.19 ± 0.09	0.50 ± 0.25
760	820	0.98 ± 0.29	<0.24	<0.74	0.53 ± 0.15	1.08 ± 0.41
760	840	0.73 ± 0.31	<0.32	<1.03	0.53 ± 0.13	0.82 ± 0.32
760	860	0.82 ± 0.26	<0.26	<0.81	0.44 ± 0.12	0.71 ± 0.34
760	880	0.69 ± 0.24	<0.18	5.64 ± 1.28	0.35 ± 0.17	0.56 ± 0.63
760	900	0.48 ± 0.24	<0.14	1.78 ± 0.55	0.54 ± 0.11	0.51 ± 0.35
760	920	0.56 ± 0.24	<0.20	<0.68	0.59 ± 0.12	0.85 ± 0.30
760	940	0.65 ± 0.18	<0.19	<0.66	0.50 ± 0.13	0.92 ± 0.30
760	960	0.88 ± 0.34	<0.24	2.59 ± 2.02	0.66 ± 0.14	0.79 ± 0.30
760	980	b	b	b	b	b

TABLE 4, cont.

**RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL
FROM 20 M GRID INTERVALS**

Grid Location N E	Radionuclide Concentrations (pCi/g)			
	Ra-226	U-235	U-238	Th-232
760 1000	1.46 ± 0.36	<0.48	5.03 ± 1.96	1.61 ± 0.27
760 1020	1.54 ± 0.38	0.97 ± 0.85	10.3 ± 2.7	1.09 ± 0.19
760 1040		b	b	b
760 1060	1.01 ± 0.43	<0.36	2.05 ± 2.22	1.03 ± 0.21
760 1080	0.83 ± 0.24	<0.15	1.07 ± 0.93	0.71 ± 0.14
760 1100	1.00 ± 0.34	<0.27	2.91 ± 1.70	0.46 ± 0.16
760 1120	0.64 ± 0.25	<0.25	3.82 ± 2.58	0.89 ± 0.20
760 1140	0.88 ± 0.35	<0.39	5.11 ± 2.86	0.73 ± 1.19
760 1160	0.88 ± 0.30	0.14 ± 0.88	3.52 ± 2.37	0.42 ± 0.14
760 766	1.29 ± 0.29	<0.37	<1.30	0.89 ± 0.18
780 820	0.58 ± 0.29	<0.14	1.41 ± 0.79	0.40 ± 0.09
780 840	0.76 ± 0.33	<0.32	<1.05	0.51 ± 0.12
780 860	2.04 ± 0.33	<0.32	<0.02	0.45 ± 0.12
780 880	0.80 ± 0.22	<0.14	0.79 ± 1.38	0.31 ± 0.08
780 900	0.69 ± 0.24	<0.16	1.92 ± 0.63	<0.05
780 920	0.81 ± 0.35	<0.20	2.43 ± 1.79	0.14 ± 0.07
780 940	1.20 ± 0.38	<0.23	<0.94	0.34 ± 0.12
780 960	0.65 ± 0.31	<0.23	0.95 ± 1.90	0.31 ± 0.12
780 980	1.01 ± 0.34	<0.29	1.46 ± 1.84	0.47 ± 0.11
780 1000	0.74 ± 0.34	0.60 ± 0.48	1.92 ± 3.06	0.23 ± 0.08
780 1020	1.33 ± 0.26	<0.31	5.50 ± 2.21	0.27 ± 0.10
780 1040	0.80 ± 0.26	<0.19	1.23 ± 0.79	0.07 ± 0.08
780 1060	1.29 ± 0.28	<0.18	1.90 ± 0.68	0.23 ± 0.10
780 1080	1.34 ± 0.44	<0.33	4.81 ± 3.08	2.20 ± 0.31
780 1100	0.76 ± 0.23	<0.22	<0.72	<0.04
780 1120	1.10 ± 0.40	<0.39	3.55 ± 3.36	1.37 ± 0.20
786 766	0.66 ± 0.30	<0.21	0.96 ± 1.48	0.70 ± 0.20
786 820	0.83 ± 0.20	<0.19	1.41 ± 1.32	0.57 ± 0.17
786 840	1.30 ± 0.52	<0.33	<1.19	0.52 ± 0.16
786 860	1.10 ± 0.35	<0.30	3.36 ± 1.38	0.26 ± 0.14
786 880	0.65 ± 0.29	<0.24	2.70 ± 1.74	<0.06
786 900	1.10 ± 0.29	<0.33	<0.94	0.56 ± 0.14
786 920	0.58 ± 0.28	<0.18	0.83 ± 1.27	0.55 ± 0.14
786 940	1.18 ± 0.40	<0.39	4.70 ± 1.65	0.78 ± 0.18
786 960	2.54 ± 0.46	0.34 ± 0.80	1.95 ± 2.18	0.85 ± 0.15
786 980	0.78 ± 0.30	0.54 ± 0.51	2.36 ± 1.07	0.84 ± 0.18
786 1000	0.75 ± 0.31	<0.27	1.62 ± 2.35	0.38 ± 0.17
786 1020	3.03 ± 0.38	<0.20	2.11 ± 0.76	0.53 ± 0.10
786 1040	0.98 ± 0.28	<0.34	1.70 ± 1.84	0.65 ± 0.12
786 1060	1.90 ± 0.34	<0.28	1.78 ± 1.12	0.64 ± 0.12
786 1080	1.43 ± 0.48	<0.28	<0.83	0.94 ± 0.16
786 1100	1.51 ± 0.41	<0.45	5.62 ± 2.46	1.94 ± 0.27

a Errors are 2σ based on counting statistics.

b Sample not collected due to surface water or other prohibitive factor at time of survey.

TABLE 5
RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL
FROM THE AREA SUBDIVIDED INTO 10 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
670	940	1.51 ± 0.30 ^a	<0.35	<1.15	0.36 ± 0.10	1.35 ± 0.61
670	950	2.03 ± 0.35	<0.19	1.71 ± 0.98	0.17 ± 0.10	0.81 ± 0.34
670	960	1.45 ± 0.26	<0.24	2.01 ± 1.61	<0.04	0.78 ± 0.38
670	970	5.45 ± 0.90	1.19 ± 1.03	4.39 ± 1.74	0.38 ± 0.22	1.50 ± 0.71
670	980	4.96 ± 0.63	2.06 ± 1.05	13.1 ± 2.3	1.28 ± 0.20	1.94 ± 0.83
670	990	3.39 ± 0.57	<0.38	6.68 ± 3.00	0.94 ± 0.22	1.48 ± 0.60
670	1000	6.18 ± 0.61	<0.37	3.38 ± 2.25	<0.06	1.05 ± 0.46
680	940	1.55 ± 0.46	<0.42	6.81 ± 2.27	0.83 ± 0.18	1.35 ± 0.68
680	950	0.71 ± 0.43	0.82 ± 0.78	5.68 ± 2.45	0.65 ± 0.23	1.24 ± 0.68
680	960	2.10 ± 0.35	0.95 ± 0.55	9.08 ± 1.22	<0.07	0.98 ± 0.44
680	970	9.95 ± 0.84	2.13 ± 1.35	29.0 ± 2.9	0.26 ± 0.10	1.14 ± 0.54
680	980	3.29 ± 0.53	0.88 ± 1.06	20.6 ± 4.8	<0.08	0.87 ± 0.55
680	990	3.08 ± 0.49	1.34 ± 0.86	27.3 ± 3.8	0.28 ± 0.14	1.50 ± 0.53
680	1000	4.46 ± 0.54	0.82 ± 1.04	8.23 ± 5.11	0.12 ± 0.18	1.25 ± 0.65
690	940	0.80 ± 0.39	0.30 ± 0.37	2.76 ± 1.52	0.95 ± 0.27	0.73 ± 0.51
690	950	0.80 ± 0.26	<0.34	3.30 ± 1.25	0.67 ± 0.14	0.89 ± 0.31
690	960	2.98 ± 0.42	0.60 ± 0.62	5.71 ± 1.19	0.47 ± 0.16	1.08 ± 0.42
690	970	3.33 ± 0.42	1.32 ± 0.79	27.8 ± 3.8	0.39 ± 0.11	1.25 ± 0.61
690	980	1.43 ± 0.39	0.89 ± 0.63	18.5 ± 1.8	0.80 ± 0.15	1.27 ± 0.51
690	990	3.06 ± 0.58	3.32 ± 1.25	55.8 ± 4.4	1.24 ± 0.25	1.16 ± 0.84
690	1000	1.48 ± 0.42	0.89 ± 0.95	13.4 ± 3.2	1.15 ± 0.24	1.46 ± 0.49
700	940	1.05 ± 0.35	<0.22	1.59 ± 1.07	0.71 ± 0.15	0.99 ± 0.69
700	950	0.96 ± 0.24	0.33 ± 0.39	3.36 ± 0.99	0.12 ± 0.07	1.25 ± 0.36
700	960	4.83 ± 0.68	2.06 ± 1.09	21.8 ± 2.6	0.28 ± 0.16	1.03 ± 0.49
700	970	1.10 ± 0.30	0.66 ± 0.74	2.47 ± 2.71	0.80 ± 0.20	1.08 ± 0.58
700	980	1.19 ± 0.41	0.66 ± 0.73	6.55 ± 3.90	0.51 ± 0.15	1.08 ± 0.41
700	990	1.10 ± 0.43	<0.22	4.48 ± 2.20	1.37 ± 0.20	1.70 ± 0.50
700	1000	1.14 ± 0.35	<0.26	4.29 ± 2.39	0.76 ± 0.19	1.42 ± 0.47
710	940	1.46 ± 0.28	<0.20	2.39 ± 1.11	0.09 ± 0.06	0.82 ± 0.48
710	950	1.36 ± 0.30	<0.31	7.63 ± 2.33	0.18 ± 0.13	1.30 ± 0.48
710	960	2.59 ± 0.49	<0.38	9.87 ± 3.26	0.85 ± 0.20	1.40 ± 0.60
710	970	1.68 ± 0.41	<0.33	4.28 ± 1.40	1.24 ± 0.22	1.27 ± 0.47
710	980	1.26 ± 0.60	<0.38	<1.26	<0.06	1.26 ± 0.78
710	990	0.96 ± 0.30	0.64 ± 0.53	2.98 ± 2.02	1.80 ± 0.27	1.10 ± 0.44
710	1000	1.20 ± 0.39	<0.32	3.60 ± 2.66	1.62 ± 0.24	0.85 ± 0.38
720	940	0.66 ± 0.39	<0.21	1.90 ± 0.83	0.43 ± 0.15	<0.27
720	950	1.41 ± 0.35	<0.27	2.48 ± 2.00	0.49 ± 0.15	0.92 ± 0.46
720	960	0.88 ± 0.40	0.28 ± 0.62	2.27 ± 2.07	0.65 ± 0.16	1.00 ± 0.49
720	970	1.26 ± 0.35	<0.42	2.75 ± 3.18	1.12 ± 0.23	0.96 ± 0.38
720	980	1.16 ± 0.31	<0.37	2.59 ± 2.26	0.78 ± 0.20	1.57 ± 0.46
720	990	0.95 ± 0.64	<0.49	4.73 ± 3.78	4.15 ± 0.53	0.91 ± 0.59
720	1000	1.05 ± 0.30	0.25 ± 0.51	4.09 ± 0.95	0.88 ± 0.15	1.11 ± 0.52

^a Errors are 2σ based on counting statistics.

TABLE 6

**RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN**

Sample Identification	Grid Location		Radionuclide Concentrations (pCi/g) ^a				
	N	E	Ra-226	U-235	U-238	Cs-137	Th-232
B1	673	977	18.8 ± 1.0 ^b	0.98 ± 0.84	8.17 ± 2.22	0.76 ± 0.13	1.07 ± 0.72
B2	674	981	119 ± 3	4.56 ± 2.97	17.4 ± 7.7	1.17 ± 0.29	<0.79
B3	676	985	1.75 ± 0.51	40.4 ± 3.3	686 ± 13	0.45 ± 0.28	0.97 ± 0.55
B4	676	996	1340 ± 10	90.4 ± 12.9	1280 ± 32	<1.02	<3.66
B5	676	998	193 ± 4	34.0 ± 3.9	543 ± 10	0.93 ± 0.32	1.53 ± 1.66
B6	677	957	240 ± 4	8.96 ± 4.21	86.3 ± 10.1	<0.30	<1.18
B7	677	999	24.4 ± 1.4	12.9 ± 2.5	189 ± 8	0.39 ± 0.16	1.11 ± 0.95
B8	680	968	1330 ± 10	<4.83	<11.4	<0.66	<2.54
B9	680	986	35.8 ± 1.5	16.3 ± 3.0	63.6 ± 14.9	<0.16	1.16 ± 0.84
B10	683	957	2600 ± 15	<7.78	<18.4	1.61 ± 1.17	<4.22
B11	683	1000	8.39 ± 0.69	5.06 ± 1.50	76.6 ± 4.5	<0.09	<0.42
B12	683	1002	1110 ± 8	21.1 ± 5.8	68.1 ± 5.7	0.68 ± 0.43	<1.98
B13	683	1004	455 ± 6	12.3 ± 5.8	27.2 ± 13.8	<0.45	<1.57
B14	684	960	c	c	c	c	c
B15	684	1002	1160 ± 8	15.4 ± 9.3	<16.1	<0.75	<2.85
B16	685	955	2340 ± 11	26.8 ± 8.6	<8.34	<0.71	<3.02
B17	685	997	1080 ± 9	23.3 ± 8.9	173 ± 25	<0.64	<2.38
B18	685	999	110 ± 4	570 ± 16	10800 ± 55	<0.52	<1.40
B19	686	990	164 ± 4	559 ± 13	14800 ± 60	<0.56	<1.59
B20	687	954	1840 ± 10	<4.00	<7.23	<0.66	<2.85
B21	690	997	55.9 ± 2.1	2.36 ± 2.31	23.5 ± 4.4	<0.15	<0.62
B22	691	990	2.49 ± 0.86	116 ± 4	2320 ± 110	0.32 ± 0.31	<0.58
B23	698	955	865 ± 8	21.2 ± 5.3	<16.0	<0.69	<2.67
B24	702	960	1900 ± 10	<3.94	<6.98	<0.65	<2.82
B25	703	947	811 ± 8	<3.73	<9.11	<0.54	<2.05
B26	705	977	74.9 ± 2.3	4.02 ± 2.49	20.8 ± 4.3	0.43 ± 0.20	<0.68
B27	706	948	22500 ± 180	286 ± 106	<94.3	<10.5	<44.9
B28	711	946	1690 ± 8	<0.99	<17.4	<0.87	<3.31
B29	713	950	39.8 ± 1.4	1.12 ± 1.10	3.48 ± 1.24	0.23 ± 0.11	1.38 ± 0.85

^a Refer to Table 3 for direct radiation levels.

^b Errors are 2σ based on counting statistics.

^c Activity too high for accurate gamma spectrometry; sample contains small white chips with 0.60 μCi of Ra-226.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No. ^a	Grid Location N E	Depth (m)	Radionuclide Concentrations (pCi/g)					
			Ra-226	U-235	U-238	Cs-137	Th-232	
H1	680	1200	Surface 0.5 1.0	1.99 ± 0.38 ^b 0.99 ± 0.23 0.70 ± 0.16	<0.24 <0.27 <0.13	1.12 ± 2.03 <0.87 0.65 ± 0.67	0.99 ± 0.18 0.10 ± 0.06 <0.02	0.56 ± 0.80 1.26 ± 0.55 0.48 ± 0.27
H2	720	776	Surface 0.5 1.0	0.81 ± 0.34 0.98 ± 0.26 0.76 ± 0.20	<0.23 <0.30 <0.13	<0.73 4.91 ± 1.96 2.67 ± 1.56	0.09 ± 0.11 <0.04 0.06 ± 0.05	1.18 ± 0.39 1.17 ± 0.42 0.77 ± 0.38
H3	750	1160	Surface 0.5 0.9	1.31 ± 0.33 1.16 ± 0.29 1.00 ± 0.24	0.34 ± 0.64 <0.22 <0.29	6.23 ± 2.56 <0.75 <0.92	0.09 ± 0.16 <0.03 <0.04	1.12 ± 0.40 0.74 ± 0.29 0.84 ± 0.35
H4	676	998	Surface 1.0	193 ± 4 2.09 ± 0.36	34.0 ± 3.9 0.41 ± 0.58	543 ± 10 4.89 ± 3.07	0.93 ± 0.32 <0.05	1.53 ± 1.66 0.96 ± 0.50
H5	683	1004	Surface 0.6 1.0	455 ± 6 7.68 ± 0.64 1.76 ± 0.29	12.3 ± 5.8 <0.38 <0.27	27.2 ± 13.8 <1.09 4.89 ± 1.86	<0.45 <0.06 <0.04	<1.57 1.31 ± 0.51 0.97 ± 0.37
H6	685	955	Surface 0.5 0.9	2340 ± 13 1.68 ± 0.38 1.43 ± 0.31	15.4 ± 9.3 <0.27 <0.35	<16.1 1.16 ± 1.88 2.21 ± 1.14	<0.75 <0.04 <0.04	<2.85 1.01 ± 0.44 1.19 ± 0.64
H7	685	997	Surface 0.5 1.0	1080 ± 9 2.06 ± 0.43 2.54 ± 0.33	23.3 ± 8.9 <0.22 <0.20	173 ± 25 1.38 ± 0.92 3.30 ± 0.70	<0.64 <0.05 <0.03	<2.38 0.94 ± 0.43 0.66 ± 0.24
H8	686	990	Surface 0.5 1.0	164 ± 4 1.64 ± 0.26 1.66 ± 0.28	55.9 ± 1.3 2.18 ± 0.71 1.72 ± 0.52	14800 ± 60 30.7 ± 2.8 36.0 ± 1.8	<0.56 <0.04 <0.03	<1.59 1.04 ± 0.30 0.71 ± 0.26
H9	702	960	Surface 0.5 0.9	1900 ± 13 1.30 ± 0.28 1.04 ± 0.26	<3.94 <0.25 <0.21	<6.98 1.36 ± 1.62 0.80 ± 1.43	<0.65 <0.04 <0.04	<2.82 0.84 ± 0.31 0.77 ± 0.33
H10	713	950	Surface 0.5 0.9	39.8 ± 1.4 1.89 ± 0.31 1.31 ± 0.22	1.12 ± 1.10 <0.36 <0.15	3.48 ± 1.24 1.75 ± 0.97 <0.38	0.23 ± 0.11 <0.05 <0.03	1.38 ± 0.85 1.41 ± 0.45 1.05 ± 0.43

^a Refer to Figure 4.^b Errors are 2σ based on counting statistics.

TABLE 8
RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample Identification	Sample Type	Grid Location		Radionuclide Concentrations (pCi/l)		
		N	E	Gross Alpha	Gross Beta	Ra-226
W1	Subsurface (borehole H5) ^a	683	1004	15.5 ± 2.6 ^b	16.5 ± 2.0	0.98 ± 0.31
W2	Subsurface (borehole H9)	702	960	278 ± 9	130 ± 4	0.92 ± 0.30

^a Refer to Figure 4.

^b Errors are 2σ based on counting statistics.

SUMMARY OF LOCATIONS ON PROPERTY C' WITH RESIDUAL MED/AEC CONTAMINATION EXCEEDING CLEANUP CRITERIA

^a Refer to Figure 7.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.
2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.
3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scan Survey of the Former Lake Ontario Ordnance Works Site - Draft Report, ORNL, Oak Ridge, TN, 1981.

APPENDIX A
INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure rates ($\mu\text{R/h}$) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at locations on the Niagara Falls Storage Site and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates ($\mu\text{rad/h}$) were determined by comparison with the response of a Victoreen Model 440 ionization chamber survey meter.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 15-30 cm intervals in all holes. The logging data was used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, Cs-137, and Th-232 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Soil samples were dried, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium and Ge(Li) detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Cs-137 - 0.662 MeV
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 μ m membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. A known volume of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Calibration and Quality Assurance

With the exception of the exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

**SUMMARY OF RADIATION GUIDELINES
APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE**

U. S. DEPARTMENT OF ENERGY

INTERIM RESIDUAL CONTAMINATION AND WASTE CONTROL GUIDELINES
FOR
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP)
AND
REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

(Review Within DOE Continuing)

Presented here are the residual contamination cleanup and waste control guidelines of general applicability to the FUSRAP project and remote SFMP sites^{1/}. A site-specific analysis will be prepared for each FUSRAP and remote SFMP site prior to determining residual contamination guidelines for a specific site. In addition, it is the policy of the DOE to decontaminate sites in a manner consistent with DOE's as-low-as-reasonably-achievable (ALARA) policy. ALARA will be considered in reducing levels of residual contamination below applicable dose limits. ALARA will be implemented using cost/benefit considerations, and applied on a site-specific basis.

The soil residual contamination guidelines were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The radium-226 and thorium-230 guidelines include an additional limitation for buildup of radon-222 decay products in buildings. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, was assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these guidelines to ensure that a particular dose limit would not be exceeded. Use of these guidelines is additionally conservative because the pathways considered in the derivation of the guidelines assume all water intake and most food intake is from the site. Also, the FUSRAP and remote SFMP sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP or remote SFMP sites decontaminated to these guidelines will not be appreciably different from that normally received from natural background radiation.

The residual contamination guidelines for surface contamination of structures were adapted from guidelines developed by the U. S. Nuclear Regulatory Commission (NRC) for decontamination of facilities and equipment prior to release for unrestricted use^{2/} or termination of licenses for byproduct, source, or special nuclear material. The waste control guidelines are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR Part 192.

^{1/} A remote SFMP site is one that is excess to DOE programmatic needs and is

located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

^{2/} U. S. Nuclear Regulatory Commission 1982 Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC.

A. RESIDUAL CONTAMINATION GUIDELINES FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following guidelines represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. A site-specific analysis will be prepared for each site prior to determining residual contamination guidelines for a specific site. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy on a site-specific basis. Site-specific guidelines and ALARA policy will be determined by DOE on a site-specific basis and an ALARA report filed on completion of remedial action at a site. Existing state and federal standards will be applied for water protection. Residual contamination limits for other nuclides will be developed when required using the same methodology^{1/} as was used for those represented here.

1. Soil (Land) Guidelines (Maximum Limits for Unrestricted Use)

<u>Radionuclide</u>	<u>Soil Criteria^{2/,3/,4/} (pCi/g above background)</u>
U-Natural ^{5/}	75
U-238 ^{6/}	150
U-234 ^{6/}	150
Th-230 ^{7/}	15
Ra-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm thick soil layers more than 15 cm below the surface and less than 1.5m below the surface.
U-235 ^{6/}	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	60
Pu-241 ^{8/}	2400
Pu-238, 239, 240	300
Cs-137	80

Sr-90
H-3 (pCi/ml soil moisture)

300
5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its guideline shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these guidelines represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m² surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these guidelines are allowable provided that the average over 100 m² is not exceeded. However, DOE ALARA policy will be considered on a site-specific basis when dealing with elevated localized concentrations.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) over any 15cm thick layers from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^9 dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 guideline was derived from the Am-241 concentration.

2. Structure Guidelines (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary

to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 R/h) above background in any occupied or habitable building.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides ^{2/}	Allowable Surface Residual Contamination ⁺¹ (dpm/100 cm ²)		
	Average ^{3/,4/}	Maximum ^{4/,5/}	Removable ^{4/,6/}
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
U-Natural, Th-232, Sr-90, Fr-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

^{1/} As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

^{2/} Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides shall apply independently.

^{3/} Measurements of average contaminant should not be averaged over more than 1 m². For objects of less surface area, the average shall be derived for each such object.

^{4/} The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should

not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm² of total absorber.

5/ The maximum contamination level applies to an area of not more than 100 cm².

6/ The amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels shall be reduced proportionately and the entire surface shall be wiped.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to store radioactive wastes in a manner representing sound engineering practices consistent with DOE's ALARA policy.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders and other items shall apply:

- a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.
- b. 5480.2, Hazardous and Radioactive Mixed Waste Management.
- c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.
- d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.
- e. 5484.2, Unusual Occurrence Reporting System.
- f. 5820, Radioactive Waste Management.
- g. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.
- h. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

1. For water protection, use existing state and federal standards; apply site-specific measures where needed.
2. Long-Term Management
 - a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.
 - b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.
 - c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 pCi/m²/s, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/l.
 - d. For water protection, use existing state and federal standards; apply site-specific measures where needed.
 - e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the requirement in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the requirements in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

- Exceptions may be made to the guidelines presented herein following analysis of the site-specific aspects of a candidate site. Specific situations that warrant consideration for modifying these guidelines are:
1. Where remedial actions would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.
 2. Where remedial actions would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future, notwithstanding reasonable measures to limit damage to the environment. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

3. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and the residual radioactive materials do not pose a clear present or future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this hazard. Remedial actions will generally not be necessary where residual radioactive materials have been placed semipermanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. Supplemental standards shall not be applied at such sites, however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that would prevail in Subpart A.
4. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be affected by remedial actions, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.
5. Where there is no known remedial action.

D. GUIDELINE SOURCE

<u>Guideline</u>	<u>Source</u>
<u>Residual Contamination Criteria^{1/}</u>	
Soil Guideline	DOE Order 5480.1A, 40 CFR Part 192 ^{2/}
Structure Guideline	40 CFR Part 192, NRC Guidelines for Decontamination of Facilities and Equip- ment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material (July 1982).
<u>Control of Radioactive Wastes and Residues</u>	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

1/ The bases of the residual contamination guidelines are developed in
ORO-831 and ORO-832.

2/ Based on limiting the concentration of Ra-222 decay products to 0.03 WL
within structures.